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THE ESO NEARBY ABELL CLUSTER SURVEY (ENACS)

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A statistically reliable distribution of velocity dispersions free from biases and systematic errors for a sample of ACO clusters is obtained. This distribution is compared with other data and model predictions.

1. *Introduction.* The present-day distribution of cluster masses contains information about important details of the formation of large-scale structure in the universe. In principle, the distribution of present cluster masses constrains the form and amplitude of the spectrum of initial fluctuations, via the tail of high-amplitude fluctuations from which the clusters have formed, as well as the cosmological parameters that influence the formation process. Recently, several authors have attempted to use either the distribution of cluster mass estimates, or of gauges of the mass (such as the global velocity dispersion, or the temperature of the X-ray gas) to constrain parameters in cosmological scenarios. For constraining the *slope* of the spectrum of initial fluctuations through the slope of the mass distribution, unbiased estimates of the mass (or of a relevant mass gauge) are required. The latter always require assumptions about either the shape of the galaxy orbits, the shape of the mass distribution, or about the distribution of the gas temperature. Therefore gauges of the total mass that are based on directly observable parameters, such as global velocity dispersions or central X-ray temperatures, are sometimes preferable. However, the use of such mass gauges also requires a lot of care. Global velocity dispersions, although fairly easily obtained, can be affected by projection effects and contamination by field galaxies.

More fundamentally, the velocity dispersion of the galaxies may be a biased estimator of the cluster potential (or mass) as a result of dynamical friction and other relaxation processes. In principle, the determination of the X-ray temperatures is more straightforward. However, temperature estimates may be affected by cooling flows, small-scale inhomogeneities, bulk motions, or galactic winds. Also, temperature estimates of high accuracy require high spectral resolution and are therefore less easy to obtain.

To obtain useful constraints on the *amplitude* of the fluctuation spectrum, it is essential that the completeness of the cluster sample in the chosen volume is accurately known. The completeness of cluster samples constructed from galaxy catalogues obtained with automatic scanning machines is, in principle, easier to discuss than that of the ACO catalogue, which until recently was the only source of cluster samples. In theory, one is primarily interested in the completeness with respect to a well-defined limit in mass. In practice, cluster samples based on optical catalogues can be defined only with respect to richness, and the relation between richness and mass seems to be very broad. A further complication is that all optical cluster catalogues suffer from superposition effects, which can only be resolved through extensive spectroscopy. Cluster samples based on X-ray surveys do not suffer from superposition effects, but they are (of necessity) flux-limited, and the extraction of volume-limited samples with well-defined luminosity limits requires follow-up spectroscopy. The large spread in the relation between

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X-ray luminosity and X-ray temperature implies that, as with the optical samples, the construction of cluster samples with a well-defined mass limit from X-ray surveys is not at all trivial. We discuss here the distribution of velocity dispersions, for a volume-limited sample of rich ACO clusters with known completeness. The discussion is based on the result of our ESO Nearby Abell Cluster Survey which has yielded 5634 reliable galaxy redshifts in the direction of 107 rich, nearby ACO clusters with redshifts out to about 0.1. We have supplemented our data with about 1000 redshifts from the literature for galaxies in 37 clusters.

2. *The Southern ACO $R \geq 1$ Cluster Sample.* The ENACS was designed to establish, in combination with data already available in the literature, a database for a complete sample of $R \geq 1$ ACO clusters, out to a redshift of $z = 0.1$, in a solid angle of 2.55 sr around the SGP, defined by $b \leq -30$ and $-70 \leq \delta \leq 0$. For our sample we selected clusters which at the time either had a known spectroscopic redshift $z \leq 0.1$, or which had $m_{10} \leq 16.9$. Judging from the m_{10}—z relation the clusters with $m_{10} \leq 16.9$ should include most of the $z \leq 0.1$ clusters. With this selection, the contamination from $z > 0.1$ clusters would clearly be non-negligible due to the spread in the m_{10}—z relation.

At present, after completion of our project and with other new data in the literature, the region defined above contains 128 $R \geq 1$ ACO clusters with a measured or estimated redshift $z \leq 0.1$. A spectroscopically confirmed redshift $z \leq 0.1$ is available for 122 clusters, while for the remaining 6 a redshift ≤ 0.1 has been estimated on the basis of photometry.

We have first shown that the 128 clusters form a sample that can be used for statistical analysis. We have estimated the completeness of our cluster sample with respect to redshift from the distribution of the number of clusters in 10 concentric shells, each with a volume equal to one-tenth of the total volume out to $z = 0.1$. It appears that the sample of 128 clusters has essentially uniform density, except for a possible ($\approx 2\sigma$) "excess" near $z = 0.06$, and an apparent "shortage" of clusters in the outermost bins. The "excess" is at least partly due to the fact that several of the clusters in the Horologium-Reticulum and the Pisces-Cetus superclusters are in our cluster sample.

3. *The estimation of the velocity dispersions.* For a determination of the distribution of cluster velocity dispersions, one must address several points. First, it is very important that the individual estimates of the global velocity dispersions are as unbiased as possible, as any bias may systematically alter the shape and amplitude of the distribution. Before calculating the global velocity dispersion we have taken special care to remove fore- and background galaxies that cannot be members of the system on physical grounds. Leaving such non-members in the system will in general lead to an overestimation of the global velocity dispersion.

4. *Comparison with other data.* The main result is that our upper limit on the occurence of clusters with σ_V above 1200 km/s is mush more severe than any previous result for optical data, namely that the space density of such clusters is less than one in our survey volume of 1.8×10^7 h^{-3}Mpc^3. It turns out that this is almost entirely due to our removal from the redshift data of those interlopers that can only be recognized on the basis of the combination of radial velocity and projected position within the cluster.

We compare also our result with distributions of the cluster X-ray temperature T_X. In transforming the T_X scale into σ_V scale we assumed that $\sigma_V^2 = (kT_X/\mu m_H)$, where m and m_H have their usual meaning. The agreement is excellent for σ_V above 800 km/s. Both the amplitude and the slope agree very well, and to us this suggests that the removal of interlopers is necessary, and that our removal procedure is adequate. It also suggests that the velocity dispersions in excess of 1200 km/s, found by others, must indeed almost all be overestimates caused by interlopers. Interestingly, the two results start to diverge below $\approx$800 km/s. Although one cannot claim that $n(>T_X)$ is very well determined in that range there is at least no contradiction with the remark that our $n(>\sigma_V)$ must start to become underestimated below $\approx$800 km/s as a result of the richness limit of our cluster sample.

The extremely good agreement between our $n(>\sigma_V)$ and the $n(>T_X)$ for σ_V above 800 km/s and for an assumed value of $\beta = \sigma_V^2/(kT_X/\mu m_H) = 1$ strongly suggests that X-ray temperatures and velocity dispersions statistically measure the same cluster property. On the basis of the data we conclude that the *average* value of β must lie between 0.7 and 1.1.

5. *Comparison with selected model predictions.* Our result confirms previous conclusions that the distributions of the velocity dispersions or masses of rich clusters do not support $\Omega = 1$ CDM models with low values of the bias parameter. The high values of the bias parameter, that one infers from the comparison are in conflict with the results for the normalization of the $\Omega = 1$ CDM models on larger scales, from comparisons with, e.g., the COBE data.

The important conclusion is therefore that, for σ_V above 800 km/s our observed distribution $n(>\sigma_V)$ provides a very powerful constraint for cosmological scenarios of structure formation. It will not be too long before detailed predictions based on the currently fashionable (or order) alternative scenarios (be it low-density, titled-spectrum, vacuum-dominated or neutrino-enriched CDM) can be compared, in a proper way, to the observational constraints. Even though it is worthwhile to try and obtain unbiased estimates of $n(>\sigma_V)$ for σ_V below 800 km/s, it would seem that the high $-\sigma_V$ tail of the distribution has the largest discriminating power.

6. *Conclusions.* We have obtained a statistically reliable distribution of velocity dispersions which, for σ_V above 800 km/s, is free from biases and systematic errors.

The observed distribution $n(>\sigma_V)$ offers a reliable constraint for cosmological scenarios, provided model predictions are based on line-of-sight velocity dispersions for all galaxies inside the turn-around radius and inside a projected aperture of $1.0\,h^{-1}$ Mpc, and provided the clusters are selected according to a richness limit that mimics the limit that defines the observed cluster sample.

The sample of ACO clusters with $|\,b\,| > 30$, $C_{ACO} \geq 50$, and $z \leq 0.1$ is $\approx 85\%$ complete. We find that the density of clusters with an apparent richness $C_{ACO} \geq 50$ is $8.6 \pm 0.6 \times 10^{-6}$ h^3 Mpc^{-3}.

The space density of clusters with σ_V above 1200 km/s is less than 0.54×10^{-7} h^3 Mpc^{-3}. This is in accordance with the limits from the space density of hot X-ray clusters. From the good agreement between $n(>\sigma_V)$ and $n(>T_X)$ we conclude that $\beta = \sigma_V^2/(kT_X/\mu m_H) \approx 1$ and that X-ray temperature and velocity dispersion are statistically measuring the same cluster property.

For the low values of the bias parameter ($b \approx 1.0$) that are implied by the large-scale normalization of the standard $\Omega = 1$ CDM scenario for structure formation this model appears to predict too many clusters with high velocity dispersions. Approximate agreement between observations and the $\Omega = 1$ CDM model can be obtained for bias parameters in the range 2 to 3.